blends which are lower than that of conventional diesel due to the cetane number decreased with the increase in methanol and ethanol mass fraction in the fuel blends. The second reason is that the methanol and ethanol have higher heat of vaporization than that of conventional diesel fuel. It was observed that the IDs of the E5 and M5 were shorter than that of E10 and M10 due to lower cetane number of the E10 and M10 blends. The TCD decreased with retarded fuel injection timing for all test fuels. The reason for the decrease in TCD is the increase in the premixed or uncontrolled combustion phase due to long ID and decrease in the diffusion or controlled combustion phase. It was revealed that, at all injection timings, TCD with blends was longer than that of conventional diesel fuel. This result can be explained by the increasing amount of the oxygen in the blends. It is known that the increase in amount of the oxygen enhances the combustion and causes to the diffusion combustion phase which becomes shorter.

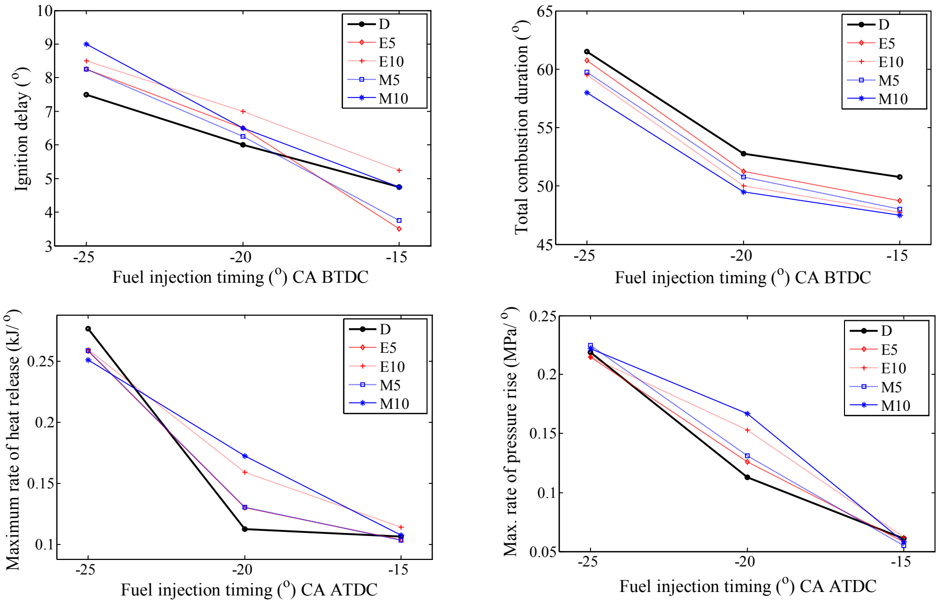

Fig.3 Effect of injection timing on the ID, TCD, $(dQ/d\theta)_{max}$ and $(dP/d\theta)_{max}$ at 1400 rpm, 40 Nm for each test fuel

As shown Fig. 2, the net heat-release profile has a slight negative dip during the ID period, which is mainly heat loss from the cylinder during the fuel vaporizing phase. It is more obvious at retarded injection timings. Because of the temperature in the cylinder increasing with retarded injection timing, the injected fuel during the ID period causes an increase in the evaporation heat. Therefore, the $(dQ/d\theta)_{max}$ decreased with retarded injection timings for all test fuels. The $(dP/d\theta)_{max}$ increased with the advancing injection timing as shown in the Fig. 3. This can be attributed to the increase in the injected fuel into the engine cylinder during the ID period, and so that produced higher the $(dP/d\theta)_{max}$ and the cylinder gas pressure. Also, there is no significant difference among the $(dQ/d\theta)_{max}$ and the $(dP/d\theta)_{max}$ of the test fuels at advanced and retarded injection timing, while at original injection timing, the $(dQ/d\theta)_{max}$ and the $(dP/d\theta)_{max}$ of the blends were higher than that of conventional diesel fuel. The main reason for this situation is that in order to obtain the same bmep from the blends, more fuel was injected into engine cylinders due to the blends have lower heating value than that of conventional diesel fuel. At the same time, it w as observed that the $(dQ/d\theta)_{max}$ and the$(dP/d\theta)_{max}$ increased with the increase in the mass fraction methanol and ethanol in the blends at original injection timing. This was caused by E10 and M10 fuel blends which have more oxygen rate than E5, M5 and conventional diesel fuel. Thereby, the combustion became better and the $(dQ/d\theta)_{max}$ and the $(dP/d\theta)_{max}$ increased.

Fig. 4 shows the average of the P_{max} achieved from 50 consecutive cycles for all test fuels and all injection timings. It was observed that the cyclic variability decreased with the retarding fuel injection timings. Specially, at 25^{o} CA injection timing, the cyclic variability of the M10 test fuel was higher than those of other injection timings. As shown in Fig.4, similar cyclic variability and the smooth operation of the engine can be achieved by using E5, E10, M5 and M10 blends when compared the conventional diesel fuel.

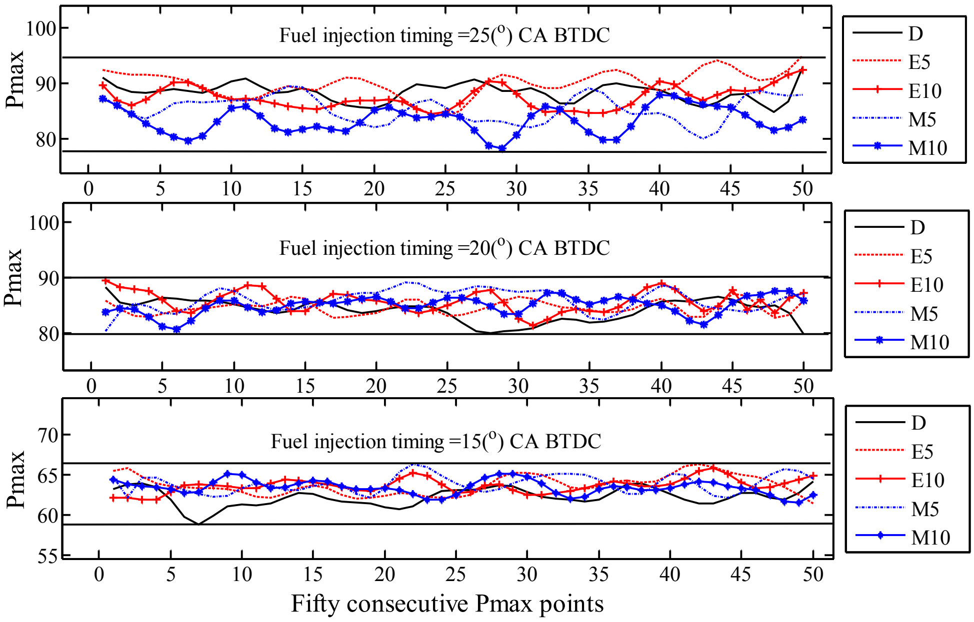

Fig.4 Effects of blends and fuel injection timing on the variation of maximum cylinder gas pressure

5. Conclusion

The paper presented the results of experimental research on the effects of injection timing on the combustion characteristics of an IDI diesel engine using the ethanol and methanol blends with diesel fuel. The following conclusions can be drawn from the current paper:

(1) The P_{max} and premixed combustion rate increased with advanced fuel injection timings for all test fuels.

(2) The location of P_{max} and the start of combustion points occurred early with advanced fuel injection timing.

(3) The ID and TCD decreased with retarded injection timing for all test fuels.

(4) It was determined that the IDs of the blends were longer than that of conventional diesel fuel at originally and advanced injection timings.

(5) An increase in the mass fraction of the methanol and ethanol in the fuel blends generally caused to increase in ID, but it decreased TCD.

(6) The retarding of injection timing decreased the $(dQ/d\theta)_{max}$ and the $(dP/d\theta)_{max}$ for all test fuels.

(7) It was found that the characteristics of $(dQ/d\theta)_{max}$ and $(dP/d\theta)_{max}$ of the blends are higher than that of conventional diesel fuel. These characteristics increased with the increase of methanol and ethanol mass fraction in the fuel blends at original injection timing.

(8) It was observed that the cyclic variability decreased with the retarding fuel injection timings. Also, the maximum cyclic variability was observed with the M10 at the advanced injection timing. The fuel blends used in the current study may replace with

conventional diesel fuel in terms of the combustion characteristics, cycle to cycle variation and smoothness of the engine operation.

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